U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-256 504

An Incentive Framework to Facilitate Solid Waste Management and Control

International Res. & Tech. Corp.

March 23, 1970

BIBLIOGRAPHIC DATA SHEET	1. Report No. IRT-R-21	2.	3. Recipient's Accession No. PB-256 504
4. Title and Subtitle An Incentive Framework to Facilitate Solid Waste Management and Control.			5. Report Date March 23, 1970 6.
7. Author(s) Robert U. Ayres, Joel Jacknow, Christine Ralph.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address International Research and Technology Corporation Washington, D. C.			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes: Prepared in cooperation with Bureau of Solid Waste Management, Rockville, Maryland.

16. Abstracts

This report contains a system analysis of solid waste accumulation, disposal and recycling. Studies on waste classification, pollution effects, natural resource potential and economics are presented.

17. Key Words and Document Analysis. 17a. Descriptors

*Solid waste disposal
*Management planning
*Materials recovery
*Industrial wastes
Systems analysis
Incentives
Government policies
Economic analysis
Process charting
Graphs(Charts)
Reclamation
Refuse disposal
Natural resources
Regulations
Recommendations

17b. Identifiers/Open-Ended Terms

*Waste recycling

17c. COSATI Field Group 13B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
National Technical Information Service Springfield, VA 22161	UNCLASSIFIED	41
	20. Security Class (This Page) UNCLASSIFIED	22. Price PC$4.00 /MF$2.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

PB 256 504

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

IRT-R-21

AN INCENTIVE FRAMEWORK TO FACILITATE SOLID WASTE MANAGEMENT & CONTROL

by

Robert U. Ayres

With Assistance From

Joel Jacknow &
Christine Ralph

-

Prepared for

ENVIRONMENTAL CONTROL ADMINISTRATION
BUREAU OF SOLID WASTE MANAGEMENT

-

March 23, 1970

INTERNATIONAL RESEARCH AND TECHNOLOGY CORPORATION

TABLE OF CONTENTS

Page

1. THE PROBLEM. 1

2. ENVIRONMENTAL MANAGEMENT FRAMEWORK 7

3. PRIORITIES 17

4. INCENTIVES RESEARCH PROGRAM. 25

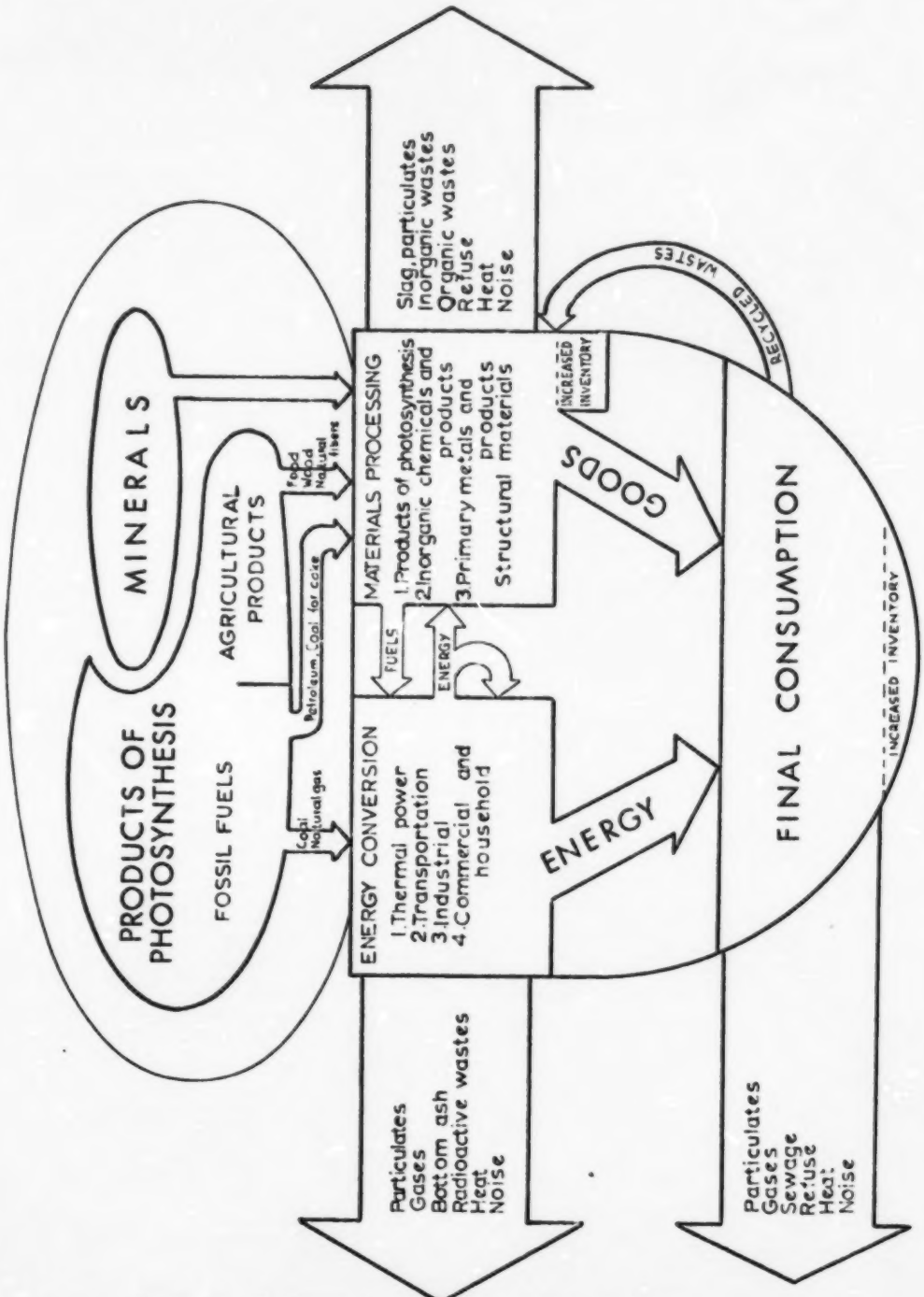
AN INCENTIVE FRAMEWORK TO FACILITATE SOLID WASTE MANAGEMENT & CONTROL

I. THE PROBLEM

The basic fact that materials fabricated into products are not "consumed" by use, but merely reincarnated into other less useful forms, has only begun to be appreciated in recent years. Since matter is conserved, except for changes of form, all of the several hundred million tons of organic and inorganic materials which annually become inputs to industrial processes must ultimately either be accumulated (i.e., added to inventories or incorporated in permanent structures), recycled or discharged into the waste stream, as suggested by the following schematic (Exhibit 1).

Accumulation and recycle account for only a small percentage of annual materials processed. Combustion of mineral fuels disposes of a significant fraction of all inputs--approximately 1450×10^6 tons in 1965--(though not without associated environmental problems). The remainder are converted into solid or waterborne wastes. These inputs are summarized in Exhibit 2.

EXHIBIT I



Source: Fortune Magazine, January 1970, (from R. U. Ayres and A. V. Kneese, "Environmental Pollution," In U.S. Congress, Joint Economic Committee, Federal Programs for the Development of Human Resources, Vol. 2, Washington 1968

EXHIBIT 2

DOMESTIC MATERIAL INPUTS EXCLUDING FUEL, 1965

($\times 10^6$ tons)

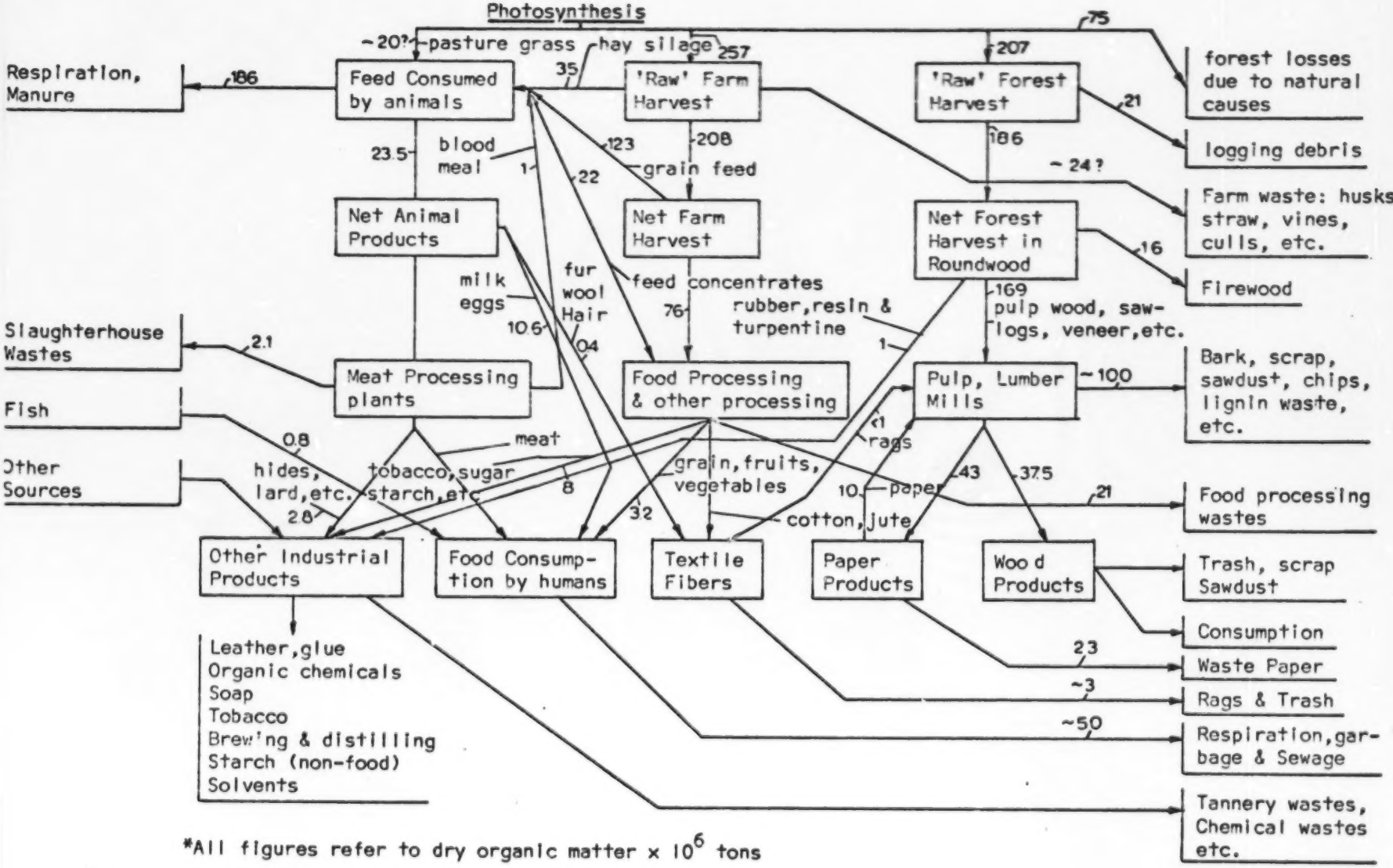
Agricultural Products--Food Crops (excluding feed)	130
Livestock slaughtered	102
Other Agricultural Products	6
Fishery Products	3
Forestry Products (15% moisture)	
Saw logs	120
Pulpwood	56
Other	42
Minerals	
Iron and Ferroalloy Ores shipped to mills	245
Other Metal Ores Processed	191
Construction Materials (sand, gypsum, gravel, stone)	1763
Other Non-Metals (including lime, clay, etc.)	149

Source: R. U. Ayres and A. V. Kneese, Ibid.

Mineral fuels used as petrochemical feedstocks and other non-fuel purposes (e.g., asphalt, tar, lubricants, waxes), account for about 5% of the total fuel energy content and, presumably of the order of 70 million tons per year. Animal feeds are difficult to estimate in toto since they include feed harvested directly by the animal (grass, alfalfa), but the tonnages involved are greater than food crops. The utilization of products of photosynthesis in the economy is suggested by Exhibit 3.

A very large fraction of the above inputs ends up each year as garbage, sewage, trash, junk, and demolition wastes. Worn-out or used-up "final" goods from the household sector alone amount to roughly five pounds per person, per day, or nearly one ton per person per year (not

EXHIBIT 3



*All figures refer to dry organic matter x 10^6 tons

Source -- R.U. Ayres and A.V. Kneese. Ibid.

including junk autos and large appliances). Industrial wastes account for nearly as much again. Rubble from demolition sites adds enormous but almost unknown tonnages. And all of these are increasing annually at a rate of several percent per year.

Since these materials cannot simply be allowed to accumulate where they are discarded, they must be removed. At present this problem largely devolves upon local governments--which now pay $5 billion per year to collect and dispose of solid wastes. This is the third largest item of local outlays.

This expenditure is an indication of the magnitude of the "externalities" (so-called) caused by the fact that when material goods are used-up or worn out, their final disposition occurs outside the marketplace where costs must be borne by the general public. Recycling wastes implies, among other things, reallocation of disposal costs to producers of goods--with consequent improvements in economic efficiency.

The disposal costs currently borne by the public are actually too low, inasmuch as the collection and treatment of solid wastes is considerably less than 100% effective. This is clear from the fact that environmental inventories of materials neither in use nor in the disposal "pipeline" are constantly increasing.

Trash and junk litter the countryside--especially any area accessible to roads and not subject to relatively continuous monitoring by property owners or municipal authorities. Regrettably, this use--or abuse--of the land detracts increasingly from the recreational and aesthetic benefits which the environment should provide to all, and which are ever more urgently needed. Thus the costs of disposal are only a part of the cost of the present system of solid waste management.

The magnitude of the waste disposal problem, in relation to local resources currently or projected to be available to deal with it, virtually demands the application of new and imaginative approaches. If an agency of government (Federal, State or Local) were to take over total responsibility for the collection and disposal of all wastes, it would--by the simple arithmetic of conservation of mass--become responsible for transporting tonnages comparable to those handled by the entire manufacturing and distribution section of the economy (except for fuels and mineral construction materials). Evidently, the best way to reduce the flow of waste into the public and environmental sectors is to retain as much as possible in the private--and productive--part of the economy. This is the primary argument for recycle.

Other arguments are not lacking, however. A number of major studies have documented the rapid rate at which high quality reserves of industrial raw materials are being depleted. Although there is no absolute shortage of most important materials, the U.S. has long since become an importer rather than an exporter of most raw materials (except coal), and dependence on foreign sources is increasing. Thus from 1930 to 1960, imports as a fraction of domestic consumption rose from 5% to 32% for iron ore, from 65% to 98% for bauxite, from 9% to 35% for lead and from 4% to 60% for zinc.[1/] Further, the average quality of ores being mined commercially declines each year. For instance, domestic copper ore averaged 3% copper in 1880; this figure dropped steadily to 0.8% in 1951-56. Comparable declines have been experienced in the case of other metals,[2/] which means more energy and more capital are required for processing.

Evidently any policy which results in more intensive re-use of materials already in the inventory would have several useful side-effects: for instance it would cut U.S. dependence on foreign sources of materials. This would reduce the troublemaking potential available to political leaders of raw-material exporting countries, and correspondingly reduce the strategic importance of protecting shipping-lanes--one of the Navy's major missions. It would cut the U.S. balance-of-payments deficit, both by reducing the need to pay for imports and by reducing the incentive to invest in new mining and shipping facilities in unstable parts of the world.

1/ See Fischman, Fisher, and Landsberg--*Resources in America's Future*, Resources For The Future, Inc., 1960.

2/ Ibid.; also C. F. Park, Jr., "Affluence in Jeopardy--Minerals and the Political Economy" (San Francisco: Freenan, Cooper & Co., 1968).

2. ENVIRONMENTAL MANAGEMENT FRAMEWORK

2.1. Goals

Goals can be formulated at many levels of breadth and scope. In the present context a useful statement of goals was recently provided by the document, *Policies For Solid Waste Management* prepared by the Ad Hoc Committee on Solid Waste Management and the Committees on Polution Abatement and Control, Division of Engineering, National Research Council, National Academy of Engineering--National Academy of Sciences:

1. *To improve the quality and coverage of the service;*
2. *To improve efficiency of operation through increased mechanization and reduced labor requirements of the system;*
3. *To reduce the accident rate and improve the skills of operating personnel through manpower-development programs;*
4. *To economically recover and adequately process for recycle increasing portions of the solid waste streams.*

Of course a broader national goal is, simply, to improve environmental quality for all the citizens of the U.S. by effective solid waste management. From this standpoint the above, more narrowly stated, objectives may be viewed as means to an end.

2.2. Strategies and Tactics

Functionally speaking, it could be argued that there are three broad strategies for solid waste management:

2.2.1. Accumulation (no action to eliminate wastes as such) possibly, but not necessarily, combined with environmental treatment or innoculation.

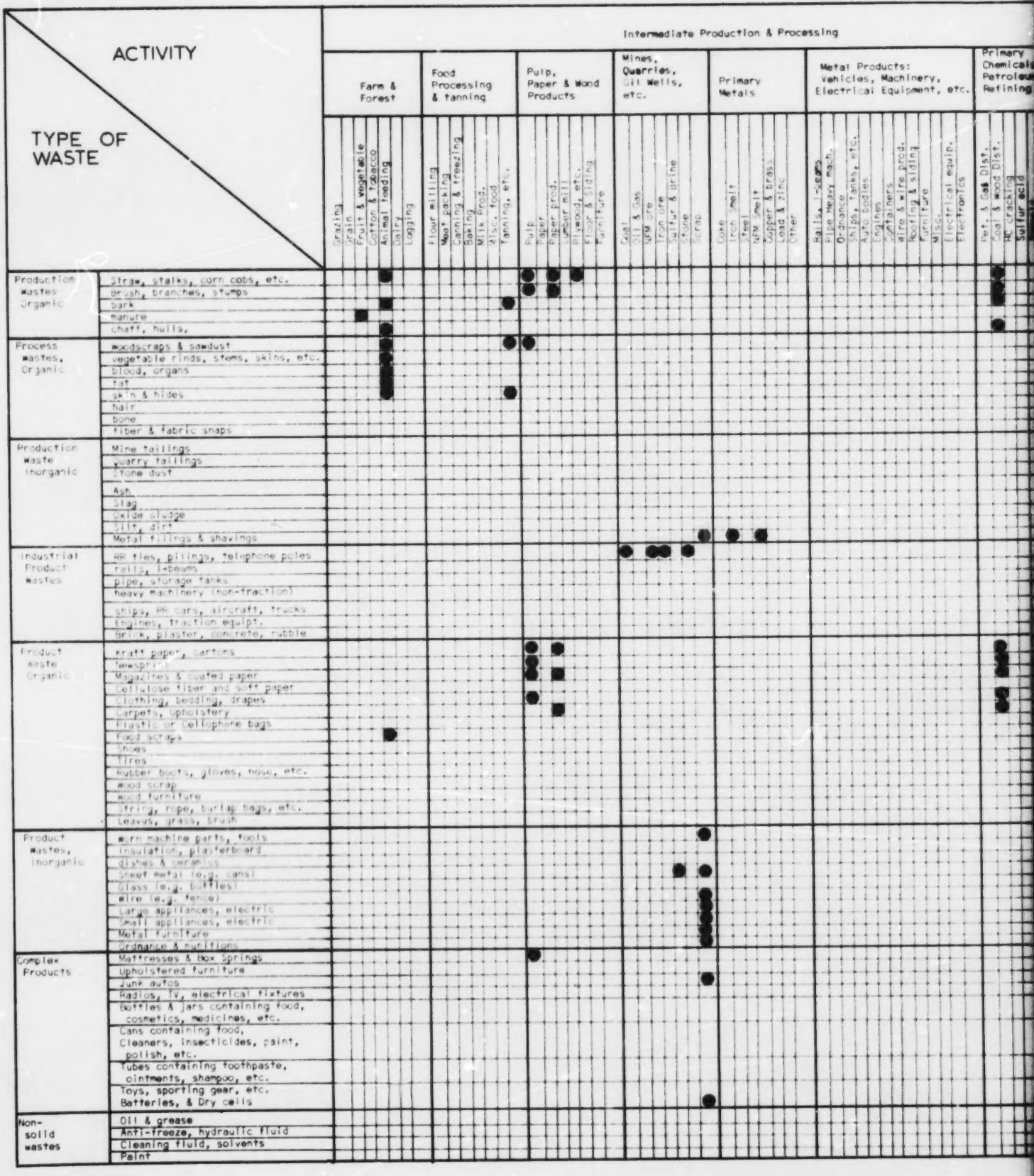
2.2.2. Disposal, including collection, treatment, dispersion diversion, dilution, or detention of wastes.

2.2.3. Recycle, including requisite process changes, product changes, and market changes to accomplish a greater degree of reuse of materials.

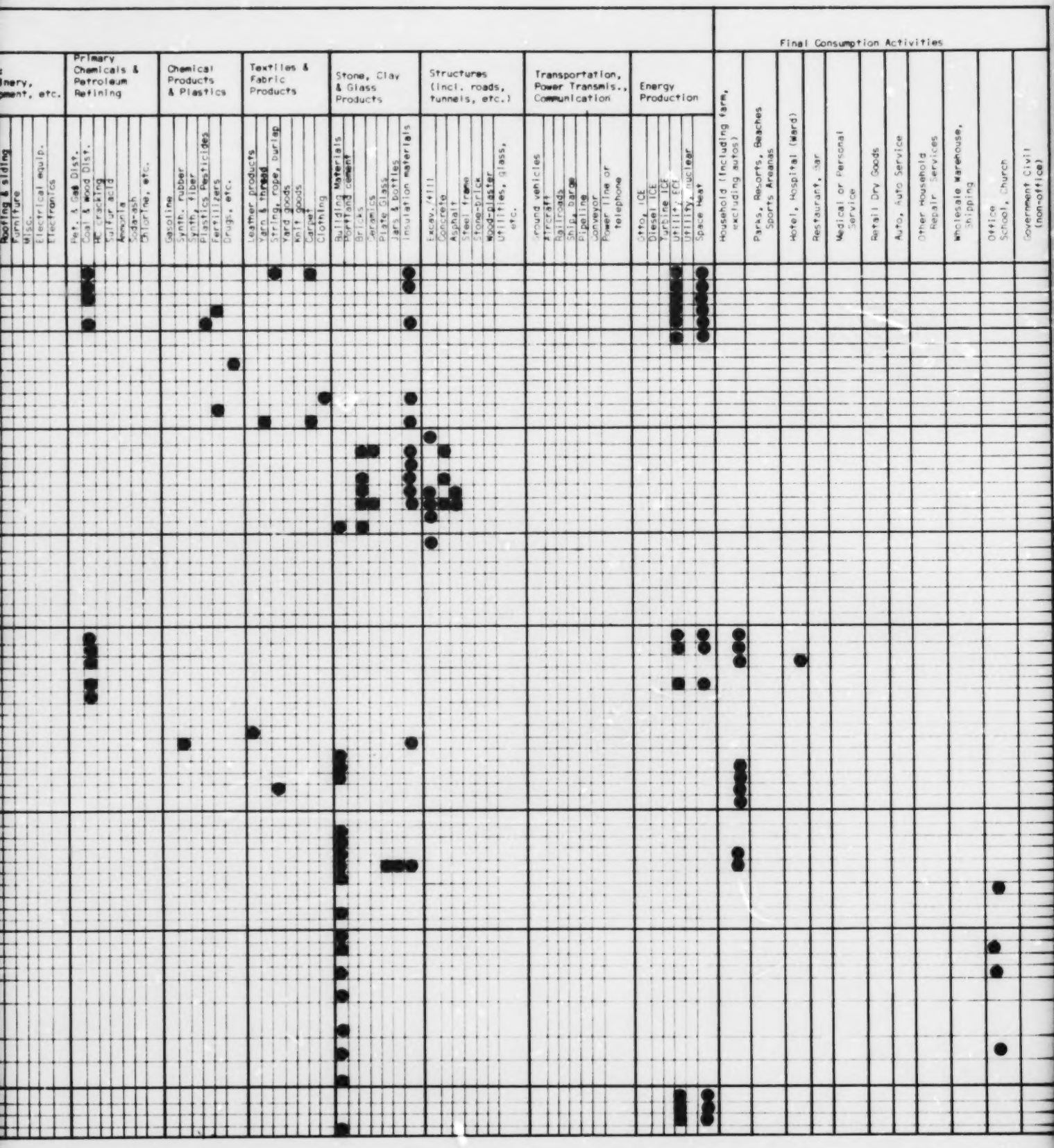
These strategies are not necessarily mutually exclusive. Indeed, some combination of all three is currently being followed in most localities. However accumulation is inconsistent with the goal of restoring the quality of our environment and cannot be tolerated indefinitely in any case. Disposal is virtually the only other strategy open at a local level (except to the extent that recycle occurs spontaneously) and its possibilities have accordingly been explored and exploited more thoroughly. With the advent of Federal assistance, it is possible and prudent to give more serious consideration to the third approach: recycle.

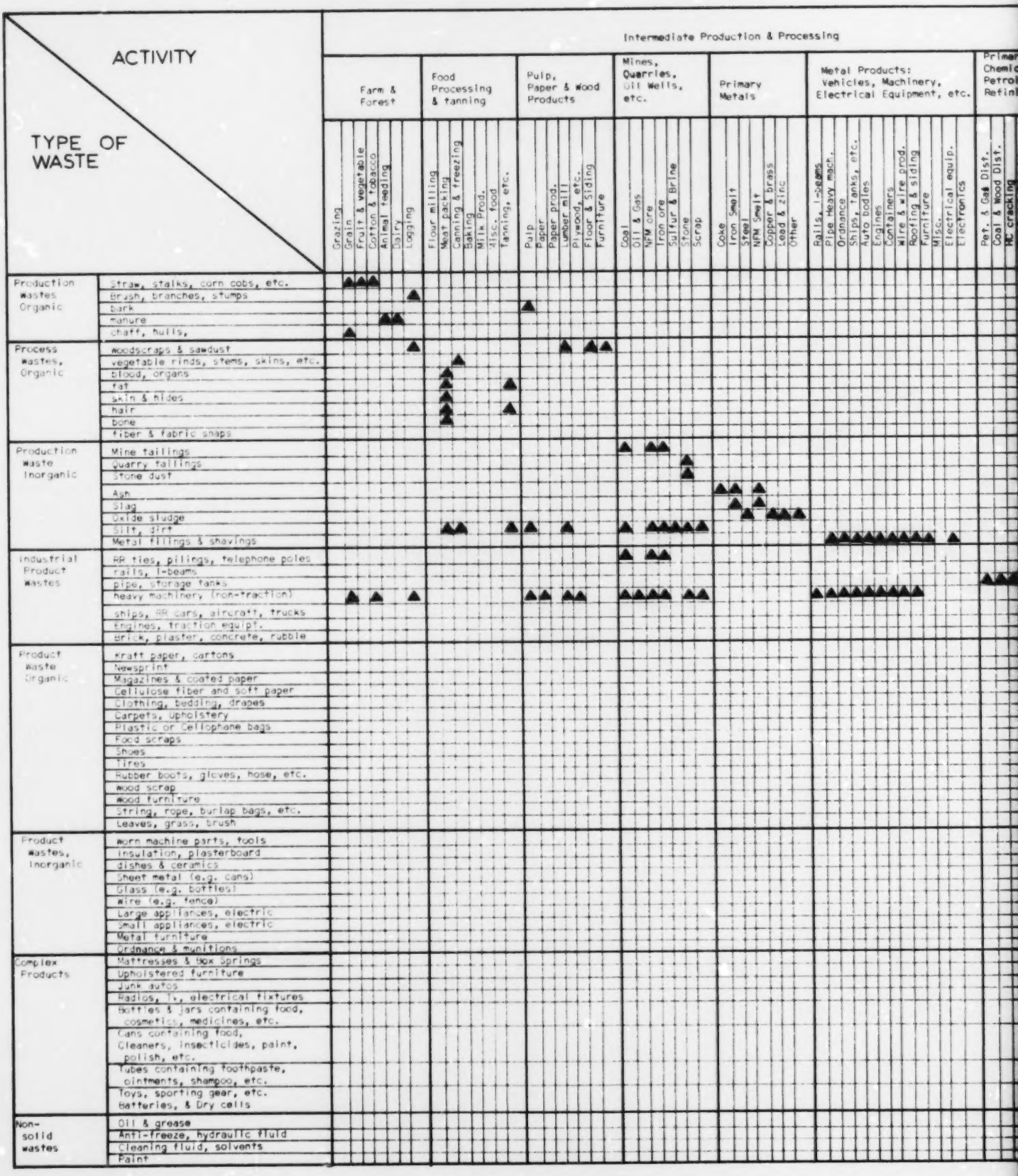
It is implicit in the fact of a quasi-free-market economy that the reuse of materials is already being practiced insofar as existing technology and costs allow. To achieve a greater degree of recycle than occurs spontaneously it will be necessary to alter or interfere, in some manner, with the mechanisms of the existing quasi-free-market. For the Federal government, at least, opportunities for manipulation of the market for industrial raw materials (of which recycled wastes are a part) are great. Exhibits 4 and 5 indicate which sectors of the economy may be considered as sources (and possible consumers) of major species of solid wastes. Exhibit 6 lists a number of cases where recycled materials may compete with natural raw materials, and notes points where the terms of the competition can be altered by changing the "ground rules" which govern the relevant transactions.

As Exhibit 6 suggests, there are many leverage points in the economy where government regulation, taxes, tariffs, import quotas, price supports, preferential procurement, and so forth can alter the economics of recycle. A more systematic classification of possible incentives is exhibited in Exhibit 7. In general one can say that recycle will be favored by any governmental actions which reduce artificial impediments to reprocessing wastes or make the use of natural materials more difficult or expensive. It is worth noting that such actions will, in many cases, be partly justified on other grounds. Thus quotas or tariffs to discriminate against the use of imported natural ores would reduce this country's serious balance-of-payments deficit as well as its excessive dependence on foreign sources. Reducing or redirecting feed grain subsidies to encourage use of farm wastes and garbage for animal feeding might have a favorable impact on the Federal Budget. Strict pollution and safety legislation affecting domestic mines, ore smelters and pulp plants--or on "throwaway" bottles--are justified quite apart from the favorable effect on recycle economics. Regulations to


ACTIVITY
TYPE OF WASTE
Intermediate Production & Processing
Farm & Forest
Food Processing & tanning
Pulp, Paper & Wood Products
Mines, Quarries, Oil Wells, etc.
Primary Metals
Metal Products: Vehicles, Machinery, Electrical Equipment, etc.
Primary Chemicals Petroleum Refining
Grazing
Grain
Fruit & vegetable
Cotton & tobacco
Animal feeding
Dairy
Logging
Flour milling
Meat packing
Canning & freezing
Baking
Milk Prod.
Misc. food
Tanning, etc.
Pulp
Paper
Paper prod.
Lumber mill
Plywood, etc.
Floor & Siding
Furniture
Coal
Oil & Gas
Iron ore
Iron ore
Sulfur & brine
Stone
Scrap
Coke
Iron smelt
Steel
N.F.M. Smelt
Copper & Brass
Lead & zinc
Other
Rails & cars
Pipe
Heavy mach.
Ordnance
Ships, tanks, etc.
Auto bodies
Engines
Containers
Wire & wire prod.
Roofing & siding
Furniture
Misc.
Electrical equip.
Electronics
Pet. & Gas Dist.
Coal & wood Dist.
Pet. cracking
Sulfur acid
Production Wastes Organic
straw, stalks, corn cobs, etc.
brush, branches, stumps
bark
manure
chaff, hulls,
Process Wastes, Organic
woodscraps & sawdust
vegetable rinds, stems, skins, etc.
blood, organs
fat
skin & hides
hair
bone
fiber & fabric snaps
Production Waste Inorganic
Mine tailings
Quarry tailings
Stone dust
Ash
Slag
Oxide sludge
Silt, dirt
Metal fillings & shavings
Industrial Product Wastes
RR ties, pilings, telephone poles
rails, I-beams
pipe, storage tanks
heavy machinery (non-traction)
ships, RR cars, aircraft, trucks
Engines, traction equipt.
Brick, plaster, concrete, rubble
Product Waste Organic
kraft paper, cartons
Newsprint
Magazines & coated paper
Cellulose fiber and soft paper
Clothing, bedding, drapes
Carpets, upholstery
Plastic or cellophane bags
Food scraps
Shoes
Tires
Rubber boots, gloves, hose, etc.
wood scrap
wood furniture
String, rope, burlap bags, etc.
Leaves, grass, brush
Product Wastes, Inorganic
worn machine parts, tools
Insulation, plasterboard
dishes & ceramics
Sheet metal (e.g. cans)
Glass (e.g. bottles)
Wire (e.g. fence)
Large appliances, electric
Small appliances, electric
Metal furniture
Ordnance & munitions
Complex Products
Mattresses & Box Springs
Upholstered furniture
Junk autos
Radios, TV, electrical fixtures
Bottles & jars containing food, cosmetics, medicines, etc.
Cans containing food, Cleaners, insecticides, paint, polish, etc.
Tubes containing toothpaste, ointments, shampoo, etc.
Toys, sporting gear, etc.
Batteries, & Dry cells
Non-solid wastes
Oil & grease
Anti-freeze, hydraulic fluid
Cleaning fluid, solvents
Paint

IBIT 4: CONSUMPTION OF WASTE MATERIALS




ACTIVITY
TYPE OF WASTE
Intermediate Production & Processing
Farm & Forest
Food Processing & tanning
Pulp, Paper & Wood Products
Mines, Quarries, Oil Wells, etc.
Primary Metals
Metal Products: Vehicles, Machinery, Electrical Equipment, etc.
Primar Chemic Petrol Refini
Grazing
Grain
Fruit & vegetable
Cotton & tobacco
Animal feeding
Dairy
Logging
Flour milling
Meat packing
Canning & freezing
Baking
Milk Prod.
Misc. food
Tanning, etc.
Pulp
Paper
Paper prod.
Lumber mill
Plywood, etc.
Floor & Siding
Furniture
Coal
Oil & Gas
NFM ore
Iron ore
Sulfur & Brine
Stone
Scrap
Coke
Iron Smelt
Steel
NFM Smelt
Copper & brass
Lead & zinc
Other
Rails, I-beams
Pipe Heavy mach.
Ordnance
Ships, tanks, etc.
Auto bodies
Engines
Containers
Wire & wire prod.
Roofing & siding
Furniture
Misc.
Electrical equip.
Electronics
Pet. & Gas Distr.
Coal & Wood Dist.
HC cracking
Production Wastes Organic
Straw, stalks, corn cobs, etc.
Brush, branches, stumps
Bark
Manure
Chaff, hulls,
Process Wastes, Organic
Woodscraps & sawdust
Vegetable rinds, stems, skins, etc.
Blood, organs
Fat
Skin & hides
Hair
Bone
Fiber & fabric snaps
Production Waste Inorganic
Mine tailings
Quarry tailings
Stone dust
Ash
Slag
Oxide sludge
Silt, dirt
Metal fillings & shavings
Industrial Product Wastes
RR ties, pilings, telephone poles
rails, I-beams
pipe, storage tanks
heavy machinery (non-traction)
ships, RR cars, aircraft, trucks
Engines, traction equipt.
brick, plaster, concrete, rubble
Product Waste Organic
kraft paper, cartons
Newsprint
Magazines & coated paper
Cellulose fiber and soft paper
Clothing, bedding, drapes
Carpets, upholstery
Plastic or Cellophane bags
Food scraps
Shoes
Tires
Rubber boots, gloves, hose, etc.
Wood scrap
Wood furniture
String, rope, burlap bags, etc.
Leaves, grass, brush
Product Wastes, Inorganic
worn machine parts, tools
Insulation, plasterboard
dishes & ceramics
Sheet metal (e.g. cans)
Glass (e.g. bottles)
Wire (e.g. fence)
Large appliances, electric
Small appliances, electric
Metal furniture
Ordnance & munitions
Complex Products
Mattresses & box springs
Upholstered furniture
Junk autos
Radios, Tv, electrical fixtures
Bottles & jars containing food, cosmetics, medicines, etc.
Cans containing food, Cleaners, insecticides, paint, polish, etc.
Tubes containing toothpaste, ointments, shampoo, etc.
Toys, sporting gear, etc.
Batteries, & Dry cells
Non-solid wastes
Oil & grease
Anti-freeze, hydraulic fluid
Cleaning fluid, solvents
Paint

HIBIT 5: GENERATION OF WASTE MATERIALS

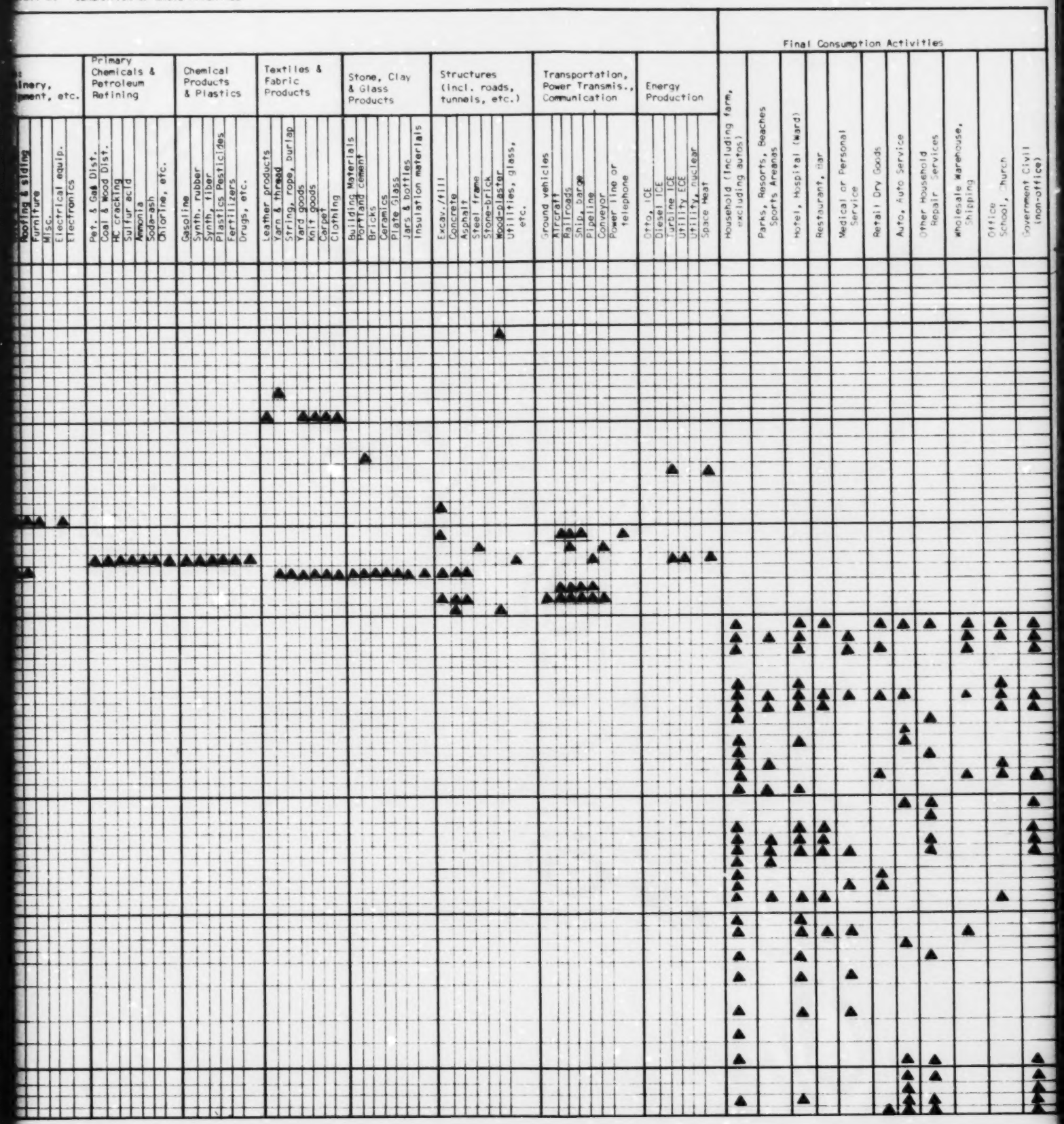


EXHIBIT 6

Purpose	Recycled Waste	Competing Natural or Synthetic Material	Possible Leverage Points
Paper Mfg.	paper and rags	wood pulp	tariffs, import quotas; pollution regulations favoring recycle, tax on new pulp
Tire Mfg.	old tires	natural or synthetic rubber	tariffs on imported rubber, tax on new tires
Steel Mfg.	auto hulks, electric appliances, scrap metal cans, etc.	iron ore	tariffs on imported iron ore; direct regulation to limit % of iron ore in steel vehicle design for easier scrap processing; strict mine safety regulations, mine beautification; revision of auto title extinction laws, freight rates
Non-ferrous Metal Mfg.	above	N.F.M. ore	
Animal Feed	Garbage (Food, vegetable rinds, skins, stems, straw, corncobs, stalks, blood, bones, skin, fat)	feed grain	pollution regulations on meat packing, reduce feed grain subsidies, promote R&D on cellulose feeding of cattle, solve manure disposal
Soil Conditioner and Fertilizer Concept	above and manure	mineral fertilizers, synthetic ammonia	solve manure disposal, pollution regulations to reduce use of soluble fertilizers; transport subsidies; use in highway program, use in Federal housing; freight rates
Shoe Mfg. Leather Goods	hides, old shoes	plastics, new leather	no tax on leather, R&D on tanning and leather uses

EXHIBIT 6 CONT.

Purpose	Recycled Waste	Competing Natural or Synthetic Material	Possible Leverage Points
Alcohol Mfg.	cellulose wastes (paper, fabric, upholstery, farm wastes, etc.)	natural gas, liquid hydrocarbons	FPC restrictions on use of natural gas for chemical feedstocks
Fiber Building Materials, insulators, etc.	above, plus old tires, plastic, shoes, hair, etc.	wood pulp, natural fiber	pollution regulations on pulp industry, import quotas, tax on new pulp and fiber
Fireproof Building Materials	ash, slag, oxide sludge, glass, stonedust, ceramics, plastic rubble	gypsum, asbestos, slate, sand	pollution regulations on mines, safety regulations for asbestos, tax on new minerials
Glass Bottle Mfg.	glass bottles	new glass	tax on new bottles at bottling plant, disposal tax (returnable) on bottled items; elimination of restrictions on reuse (e.g. of liquor bottles); tighter safety requirements favoring heavier bottles, etc.
Plastic Bottles	plastic bottles	new plastic	

EXHIBIT 7

Strategies to Increase Recycle

(1) Government purchase (or differential price purchasing)

- (a) Of wastes (for resale to scrap processors)
- (b) Of reprocessed materials, for direct use
- (c) Of transportation or other services required for reprocessing

(2) Private purchase with government subsidy (or easy credit, tax abatement, etc.)

- (a) to collector
- (b) to scrap wholesaler
- (c) to scrap processor
- (d) to scrap transporter
- (e) to material user

(3) Tax on competitive natural raw materials

- (a) tariff (on imports only)
- (b) excise tax (disposal tax) on materials from natural sources

(4) Tax on waste producers

- (a) at point of sale
- (b) at point of disposition
- (c) at point of manufacture

(5) Elimination of subsidies for Natural raw materials

- (a) agricultural price supports
- (b) mineral depletion allowances
- (c) stockpiling

(6) Regulations tending to encourage re-use of waste

- (a) quota (or embargo) on materials from natural sources
- (b) quota (or embargo) on imports
- (c) prohibition on abandonment or littering, etc.
- (d) strict enforcement of pollution, safety, etc., standards for producers of natural raw materials or "throw away" products
- (e) strict standards (safety, toxicity, etc.) on competitive products themselves.
- (f) composition of final product

(7) Elimination of regulations tending to discourage re-use of waste

- (a) prohibitions on re-use
- (b) discriminatory labelling laws (e.g. on reprocessed wool or motor oil)
- (c) difficulties in transfer or extinguishing of title to abandoned autos
- (d) building codes geared to traditional materials
- (e) regulated freight rates

discourage indiscriminate use of synthetic nitrates and mineral fertilizers--at least in heavily populated (urban) areas--would help solve the eutrophication problem in rivers and lakes (from run-off), while at the same time reducing the economic disadvantages of using compost and manure. A guaranteed market for compost for highway beautification and other public purposes would help restore the natural beauty of the environment, quite apart from its effect on the economics of composting.

Though a wide variety of strategies can and should ultimately be pursued simultaneously, most of the items listed in Exhibit 7 have one of these drawbacks: (i) strategies (5) and (7) involve eliminating preferential treatment for certain producers or other groups with powerful political support; (ii) strategies (1) and (2) require additional government outlays at a time of extremely tight budgetary limitations, while (iii) strategies (6) and (7) apply mainly to special cases, rather than to the whole range of waste products. The first point is not an argument against making the attempt to eliminate preferential treatment, especially where the original reasons for it are no longer applicable. Neither is the third point an argument against taking action wherever it is possible to do so. However fast and effective results are most likely to be obtained by a combination of strategies (1) or (2) with (3) or (4)--the extra outlays being covered by extra revenues. For a variety of reasons it may be desirable to tie revenue and outlays so closely together that the words "tax" and "subsidy" become inappropriate and the role of the government is reduced to that of monitor and umpire, rather than tax collector and spender.

Hence the attractiveness of the notion of a "disposal charge"[1/] to be added to the purchase price of every product and allocated to pay the costs of both recycle and disposal of wastes in optimum fashion. By forcing producers, in effect, to "internalize" the costs associated with the ultimate disposal of their products, the competitive free market for goods and services will actually be strengthened, by the elimination of the distortions introduced by misallocation of resources due to non-market effects or "externalities."[2/]

1/ Analogous to the notion of "effluent charges" now gaining in support among some resources economists.

2/ The same institutional structure would be effective in "internalizing" costs associated with air and water pollution.

2.3 Role of Research

The necessity for research is seldom questioned where hardware development is involved. On the other hand, where the problem to be solved is largely institutional--as in the present case--the need for research prior to action is apparently less obvious. The U.S. government (both the Executive Branch and Congress) has embarked repeatedly on multibillion dollar action programs in many fields, especially in the past decade, without adequate preparation or knowledge of the probable effects in detail. The unfortunate consequence of this is that most "human resources" programs are relative failures in terms of their explicit objectives, while a good many are outright scandals.

The role of economic research in the present context, then, is to anticipate problems and attempt to find answers (or at least, the right questions) before our ignorance is revealed in the glare of misspent tens or hundreds of millions of dollars. The key questions that need to be answered before committing the Federal Government to a course of action are: what will it achieve? what will it cost? and who will pay the cost?

Translated into specifics, we need data on the physical quantities of solid wastes (by type, not in the aggregate)[1/], their geographic location, their physical and chemical characteristics, their potential for re-use, the processing required and the cost of that processing. Most important of all, we need data on the elasticities of supply and demand in all of the markets which actually or potentially produce, consume, or compete with solid waste materials. For instance, it is important to know the impact of a change in the price of bottles and cans on the packaging industry, and on the convenience food (and beverage) industry. If a 2 cent or 5 cent tax were added to each can (or bottle) how much would sales and profits be affected? On the other hand, if a 2 cent or 5 cent refund were offered for returns of cans or bottles, what percentage would be returned: How far would

---

1/ Some data in this area is now being gathered by the Bureau of Solid Waste Management (BSWM). For example, in research supported by the BSWM, "A Batch Retort Pyrolysis of Solid Municipal Waste," D. A. Hoffman, City of San Diego, has surveyed the refuse going into two landfills in the San Diego area for a total of 40 days. Other relevant recent efforts in this area include a study of the starch content of the compost produced at the Johnson City composting plant (a joint BSWM-TVA project), an investigation to determine the BTU value of solid waste, and a statistical sampling study to determine the heterogeneity of municipal waste. The latter two are in house BSWM efforts.

people in various economic categories bring them? At what price level would householders in various income and educational brackets segregate their cans and bottles from other forms of refuse if it were collected door to door? If a price of $1 or $2 were offered for each old tire returned to a scrap dealer, how many fewer tires would be turned or tossed in rivers or abandoned in empty lots? At what price would service stations find it worthwhile to act as intermediate collecting stations for a central reprocessing plant? How far will a junk car be hauled to collect $5? $10? $25? At what price would entrepreneurs find it profitable to go around collecting abandoned hulks?1/

The list of pertinent questions is almost endless and intelligent action need not await a thorough understanding of all the behavioral factors implicit in the above. On the other hand, it would be disastrous to add a 15¢ disposal charge on tin cans if it should turn out that the extra price significantly deterred buyers--thus penalizing the canning industry--but did not induce returns of cans. In a complex program, this kind of mistake can only be avoided by an unlikely degree of luck, or by prior research. It is primarily to this end that the research programs(s) outlined hereafter are directed.

Technological R&D is also needed. A number of potential opportunities for recycle would be facilitated by technological progress in areas. Methods for separating copper, aluminum, lead and other non-ferrous impurities economically from scrap iron would improve the market for junk auto bodies, or "Number Two Bundles." Soluble glass, biodegradable plastic, shatterable or oxidizable cans would be of great value to the packaging industry. Methods of re-using rubber and synthetic fibers, bleaching used paper (without water pollution), or extracting cellulose fiber, alcohol or hydrocarbons from mixed refuse would be potentially valuable, etc.2/ However, first priority should go to economic studies directed toward defining the problem, and optimizing the allocation of resources to solve it. This ordering of priorities is reflected in

---

1/ A great deal of information which can be used to answer these questions is contained in the U.S. Bureau of Mines study "Automobile Disposal--A National Problem: Case Studies of Factors that Influence the Accumulation of Automobile Scrap."

2/ Both the Bureau of Solid Waste Management and the Bureau of Mines are now supporting significant research in some of these areas. The BSWM is supporting research on various new soluble glass formulations which will dissolve upon breaking of a thin impervious surface layer (S.F. Hulbert, Clemson Univ.), the conversion of cellulose to sugar (R.D. Fagan and A.D. Converse, Dartmouth College), the chemical transformation of solid wastes (V.H. Freed, Oregon State Univ.), as well as two projects on the microbiological conversion of cellulose to protein (J.D. Douros and D.M. Updegraff, Univ. of Denver; and C. Callihan, Louisiana State Univ.). Research at the Bureau of Mines has shown that mixed refuse reacted with carbon monoxide and steam at 380° C and 1000° PSI, will yield 1 barrel of "petroleum" per ton (Chemical & Engineering News, November 17, 1969).

the research program outlined in the following section.

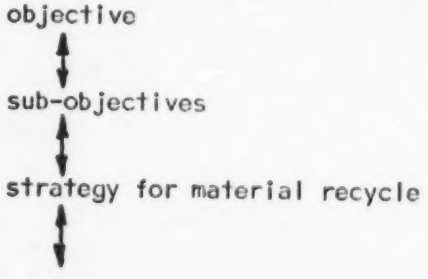
The question of relative priorities for attention among the large number of waste producing industries, waste materials, possible waste-consuming industries and possible waste-conversion processes cannot be resolved once-for-all, since priorities for research must reflect factors which vary with time. Such variables include the intensity of public concern with particular waste problems, the economic prospects of affected indust ies, local institutional interactions within a region and, of course, technological opportunities opened up by new inventions or discoveries. The latter point is important, since the "field" of waste-reprocessing has so little history and research and it is so limited and scattered that there exists little or no basis for forecasting the extent or direction of technological progress in the immediate future--in contrast to the situation in well-developed and well-funded areas such as aerospace or telecommunications. Consequently, we have proposed a procedure for determining (and reassessing) priorities on an on-going basis, which can be used by the program managers and policy-makers. This procedure is described in the next section.

3. PRIORITIES

Though research funds are not (and need not be) committed five years in advance, it is nonetheless useful to display a five year program in reasonable detail, for several alternative budgetary levels. This requires some specification if relative priorities, even though many of the factors which ought to be taken into account should, themselves, be determined by the initial phases of the research program. Thus, it is anticipated that the five-year plan itself, would undergo a gradual process of evolution and refinement.

Where choices must be made among a number of basically similar and equally researchable projects, one must seek a common measure applicable to all--in this case, a measure of the benefits of a successful outcome, in relation to the costs of the effort. As applied to an investment decision, for instance, the "benefits" would be defined as the "discounted present value" of the expected return (summed over all future years) of the investment, while the "costs" would be the discounted present value of the expected costs, again summed over all future years. Estimating these quantities in an uncertain economic environment offers a considerable challenge, but less so than the corresponding procedure where the research is sponsored by a government agency for the public benefit, especially where many of the accrued benefits are not priced in a market place. In the latter case, which we are presently faced with, a somewhat more abstract procedure is called for.

For purposes of this report, we propose to assess relative "benefits" of comparable research projects in terms of their contributions for achieving a specified--and, hopefully, agreed upon--objective. The chain of logical connections might look as follows:



Each double arrow represents a relationship which might be termed relevance, and each link in the chain therefore has relevance to any or all of the other links. Specifically, of course, we wish to evaluate the relevance of research on various waste materials to the overall objective. This can be done by making a number of individual qualitative judgments, which can be combined (by straightforward algebraic manipulations) to yield a composite final result which will, hopefully, be more refined and less arbitrary than any single one of its components.

Suppose, for instance, that we identify

m sub-objectives
n strategies
p activities
q materials

The material-activity matrix then has q x p elements, the activity-strategy matrix has p x n elements, and the strategy-objectives matrix has n x m elements. The first step in the procedure is to agree on an overall objective and estimate, numerically, the "weights" of the m sub-objectives. This is carried out explicitly in Exhibit 8, where the numbers represent the average judgments of several IR&T staff-members. These evaluations will obviously be subject to change as new information or deeper insights are brought to bear on the problem.

An obvious refinement on the procedure outlined above would be to solicit views on the relative importance of various objectives and problem areas from a larger and more representative group of experts both in and outside the BSWM. This evaluation process could also be subjected to some systematic technique for review, correction and iteration such as "Delphi"[1/] or "SYNERGI".[2/]

1/Gordon, T. J. and Olaf Helmer, Report on a Long-Range Forecasting Study Report P-2982, The Rand Corporation, Santa Monica, California, 1964. N. Dalkey and O. Helmer, "An Experimental Application of the Delphi Method to the Use of Experts," Management Science, Sept. 1963.

2/SYNERGI, A New Approach to Value Judgment, Edward Ayres, IRT-P-6, 1969.

EXHIBIT 8

Overall Objective

Score

	100	• To reduce the disutility of waste matter.

This can be divided into the following sub-objectives:

A.	40	• To reduce waste disposal costs to local communities
B.	15	• To reduce unsightliness and odor due to litter, garbage, etc.
C.	2	• To reduce health hazards from waste accumulation
D.	2	• To reduce safety hazards
E.	9	• To reduce liquid waste (from solid waste disposal)
F.	5	• To reduce gaseous waste (from solid waste disposal)
G.	7	• To reduce external diseconomies to production processes due to use of the environment for waste disposal or dilution
H.	10	• To reduce rate of consumption of limited natural raw materials
I.	10	• To reduce dependance to foreign sources and vulnerable lines of supply

EXHIBIT 9

IMPORTANCE OF PROBLEM AREAS

Sub-Objective Weights	40	15	2	2	9	5	7[b]	10	10	Sum
Sub-Ojectives	A	B	C	D	E	F	G	H	I	Σ
Auto-Hulks	10	15	0	10	0	15	20	35	35	1,560
Tires	2	5	0	5	0	15	5	8	10	435
Paper Products	30	25	0	0	20	20	35	15	20	2,450
Cans	9	20	0	10	0	0	25	20	15	1,205
Bottles	9	5	0	50	0	0	10	0	0	605
Plastic & Foam	5	5	0	5	0	10	0	2	0	355
Demolition Rubble[a]	3[a]	3	0	10	10	10	0	5	5	425
Yard Trimmings	12	2	0	0	0	15	0	0	0	585
Organic Garbage	16	15	100	0	70	15	0	0	0	1,700
Large Appliances	4	5	0	0	0	0	5	15	15	570

(a) Currently handled by contractor, hence not an expense to cities.

(b) Primarily to tourist/recreation-based sectors of the economy.

Column sums total 100

The three matrices can also be estimated in the same manner, in principle. Alternatively, one can conceptually combine two or even all three matrices into a single one, if more detailed treatment seems unwarranted. In the present instance we use this simplification, defining a q x m "materials-sub-objective" matrix as shown in Exhibit 9.

A typical entry represents the relative contribution which would be made to meeting a given sub-objective by completely recycling a given material. The numbers in each column are constrained to add up to 100 (thus representing percentages) the weights to be attached to each waste material are derived simply by matrix-multiplying the m-element sub-objective vector by the q x m element matrix, resulting in a q-element vector whose components represent the importance--or priority--to be attached to recycling each waste material.

Note that the elements in the columns of the materials-objectives can be fairly well determined (in principle) by detailed analysis. Such analysis is beyond the scope of the present project, but should be undertaken at an early phase of the overall research program.

The relative benefits to be expected from efforts expended on recycling various waste materials, as estimated by the above procedure, explicitly assumed equal "researchability", or--in some sense--equal fractional increases in recycle "capability" for equal research efforts. We did not, in other words, take into account any differences in the intrinsic difficulty of increasing the degree of recycle of different waste materials. Such differences clearly exist and relate to:

(a) the elasticity of the market for the "final" product (prior to becoming a waste).
(b) the need for stability in the potential market for the reprocessed material.
(c) the complexity of the material and the intrinsic difficulty of separating its components.
(d) the physical dispersion or disaggregation of the waste after normal use, which affects the cost of re-aggregation, collection and transportation.

The benefits derivable from a recycle project if it succeeds are not the sole measure of its desirability or priority; equal weight must be put on the cost-effectiveness of the project, or the probability of success as a function of effort expended on both research and implementation. It must be recognized, here, that the usual law of declining marginal returns applies very markedly to research. While the outputs of research, per se, are extremely difficult to measure, it has been estimated by some authorities that effective output increases only as the cube root or fourth root of expenditure. (That single inventors and small groups so often manage to compete successfully with major corporations or large institutions is essentially traceable to the low productivity of extra expenditures or manpower). One consequence is that an "easy" problem may be solved almost casually, whereas a modest increase in difficulty often results in a very large increase in costs. Hence, if the relative tractability of two problems can be meaningfully distinguished by means of measures such as the foregoing, the probable costs will probably differ in a dramatic way. Our attempt to apply these measures is displayed in Exhibit 10.

Each row is filled in using the following scale, where a high number implies a greater obstacle:

8 = major
4 = moderate
2 = some
1 = slight

For convenience we simply add the "scores" for each waste material and take them to be measures of the likely difficulty of the problems to be faced. The ratios of weighted value to difficulty are also shown in Exhibit 10.

On the basis of our previous remark about the low marginal productivity of money and manpower as applied to research, the ratios of research costs should be the third or fourth power of the ratios of difficulty.

EXHIBIT 10

PROBLEM DIFFICULTY

MEASURE	Auto Hulks	Tires	Paper	Bottles	Cans	Plastic & Foam[a]	Demolition[b] Rubble	Yard[c] Trimmings	Garbage[d]	Appliances
Elasticity of market for "final product" (prior to disposal)	1	1	4	8	8	4	1	1	1	2
Scale of reprocessing plant	8	4	8	1	4	4	4	1	2	8
Complexity of "final product" (i.e. waste)	8	2	4	1	4	2	4	1	2	8
Physical dispersion of waste	2	4	8	4	8	2	1	1	2	2
TOTAL DIFFICULTY	19	11	24	14	24	12	10	4	7	20
BENEFIT/DIFFICULTY RATIO	82	41	102	50	43	30	43	146	244	29

(a) assuming reprocessing into crude building materials, insulation, etc.

(b) assuming use as fill or building materials.

(c) assuming composting.

(d) assuming composting or animal feeding.

Thus, if project A has unit cost and unit "difficulty", while project B is rated as 1.5 on the scale of difficulty, its likely research cost would be in the range

$$(1.5)^3 \quad \text{to} \quad (1.5)^4$$

or

$$3.4 \quad \text{to} \quad 5.1$$

on the same scale (i.e. $). The above is hardly a precise relationship, and we do not attempt to use it explicitly in estimating costs. Nevertheless, we do point out that research costs do typically increase very steeply with the difficulty of the problem to be solved.

If research costs alone were considered in the "benefit-cost" formulation, the highest research priority would tend to go to the easiest (i.e., most researchable) waste problem--notably recycling yard trimmings (leaves and grass) and garbage. Interestingly enough, these particular problems have <u>in fact</u> received the highest priority in the past years and--from a technological point-of-view--can be viewed as essentially state-of-the-art due to the development of composting processes. Implementation still awaits the development of a market for the product, of course.

As a rule, most of the cost of solving a problem is attributable to the costs of implementation (as opposed to research) which increases more nearly in proportion to relative difficulty. In the absence of detailed economic studies--which appear to be essential--we have elected to use the ratios of "benefits" to "difficulty", displayed in Exhibit 10, as the basis for selecting preliminary priorities for undertaking research in this field. As program implementation costs are determined by further research, these numerical estimates can be improved.

4. INCENTIVES RESEARCH PROGRAM

4.1 Environmental Inventory, Projections and Surveillance (1st year and continuing)

4.1.1. Carry out a survey, using existing sources of data, to estimate the physical quantities of various categories of waste products now in the environmental inventory (i.e. "used up" but not recycled in an acceptable fashion), and the percentages now being recycled. This survey should cover most (if not all) of the items listed in Exhibits 4-5, but emphasizes the items listed in Exhibit 8. This information would be of value not only to BSWM but also to local governments in setting goals and planning for future solid waste collection and disposal facilities. It would also be indispensable to entrepreneurs wishing (for instance) to identify the most favorable locations for investments to exploit newly developed reprocessing technologies.

4.1.2. Develop a solid waste output model to estimate the rate of increase (or decrease) of each of these environmental inventories and recycle rates in terms of standard econometric indices and other relevant variables. Technological substitution should be treated explicitly in this model. In subsequent years the model should be refined on a regional basis.

4.1.3. Recommend improved means of monitoring the environmental inventories and reprocessing rates on a continuous (i.e. year to year) basis.

4.1.4. Identify obstacles of a technological nature which inhibit recycle of each of the critical waste materials.

4.2 Study of Automobile Recycle (1st year and continuing)

4.2.1. Estimate the price elasticity of the automobile market among various income and other pertinent groups in the U. S. population, based on evidence derived from historical cases.

4.2.2. Identify the general criteria an effective "bounty" scheme must satisfy in terms of the incentives to major sectors, viz. auto manufacturers, dealers, users, scrap collectors, scrap processors, the steel industry, and localities. The practicability of applying differential bounties based on local population density, shipping costs, income-level or on characteristics of specific model-years, should be investigated.

4.2.3. Devise a procedure (or "model") to determine the economically "optimum" reallocation of resources (i.e. bounty money) among the above-mentioned sectors to achieve a given objective in terms of increased recycle, subject to the general criteria identified in 4.2.2. This model should specify both tax and subsidy levels, taking into account the need to make adjustments from time to time as economic and environmental conditions and objectives change.

4.2.4. In connection with the auto recycle study, an expansion of past studies of the economics and technology of scrap utilization by the steel industry should be undertaken.[1/] Such a study should identify the major obstacles to greater use of scrap auto bodies, the technological possibilities for overcoming these obstacles, and the probable costs of doing so in various time-frames.

4.2.5. Starting in the second year one or more recycle demonstration projects should be initiated. Funds for the systems management and monitoring function are explicitly allowed for in the proposed budget. However, funds for operational costs (i.e., "bounties" or "subsidies") are presumed to be provided from another source. At this time we have no basis for picking an appropriate sum.

1/See "Iron and Steel Scrap Consumption Problems," Business and Defense Services Administration, U. S. Department of Commerce, March 1966, Also "Automobile Disposal--A National Problem," U. S. Bureau of Mines, op. cit.

4.3. Organic Material (Garbage, Yard Trimmings)

Starting in the second year a study should be undertaken of the various possible ways in which actions of the Federal government in the area of taxation and/or regulation could tend to create a viable market for animal feed compost or other recycled organic products. Such a study should show in detail how Federal procurement regulations, freight rates, agricultural price supports, pollution standards and so on would affect these potential markets.

The economic study of recycling organic garbage (via compost and treated sewage solids) should include consideration of the costs of transporting all household refuse (except paper and possibly cans) through the existing sewer lines and treating garbage and sewage together. This study should also consider the economics of utilizing the final product as a fuel for electric power production.

4.4. Paper Products

4.5. Bottles

4.6. Cans

Starting in either the second or third year (depending on budgetary levels) a coordinated attacked on the problem of packaging materials should be begun.

A cooperative industry-government project might be initiated to develop a "total systems" approach to the disposal of packaging materials used for convenience goods in households. The rationale for HUD's "Project Breakthrough" might be pertinent. Industry should be solicited to greatly accelerate its R&D efforts related to such things as:

Soluble glass

Biodegradable plastic containers

Metal cans which could be shattered, shredded, ground up or rapidly oxidized by simple treatment at the household level. Mechanical or heat treatments should be explored. Household grinders or "disposalls" capable of handling all kinds of

packaging materials (including cans) should be explored.

Provisions should be made to support research on valid new concepts for institutional or technological innovations tending to increase the extent of recycling. As an example of such a scheme, the possible use of newspaper delivery trucks (and personnel) to collect old newspapers and other paper from households--and appropriate incentives to publishers to elicit their cooperation--might be worth serious attention. A requirement that newsprint contain a specified fraction of reprocessed pulp would create incentives (which the pulp processor would pass on to the publisher to facilitate such a return flow.)

As in the case of automobile hulks and organic materials, a broad study should be undertaken of the impact of actions of the Federal government in the area of regulatory policy, tax benefits and direct Federal budgetary outlays on incentives for recycling materials. Such a study should show in detail how changes in price supports, import quotas, tariffs, stockpile levels, Federal procurement regulations, freight rates, safety or pollution standards, etc., etc., would affect the potential markets for reutilization of various packaging materials.

While it would be tempting to study newspaper and other paper products, bottles and cans separately--due to the differences in the materials involved--we strongly recommend a unified study which will focus attention on the important interproduct competitive and substitution relationships, as well as the economic problems which are common to all packaging materials, i.e., the determination of price elasticities.

Again, as in the case of auto bodies and organics, a number of recycling demonstration projects should be initiated in later years, probably in parallel. The newspaper collection scheme mentioned above would be a plausible candidate for such a pilot project.

4.7. Demolition rubble

4.8. Tires

4.9. Plastic and Foam

4.10. Large Appliances

Starting in the third year or later years, studies of the above lower priority materials should be undertaken. We lump them together not to suggest that they have much in common with each other (unlike the case of packaging materials) but because in general terms the approach is similar to the one already described, viz.

- an impact/market study for each material
- R&D as required to overcome key technological obstacles to recycle (as identified by 4.1.4)
- recycle demonstration projects on a small scale, to identify institutional and management problems and develop appropriate strategies to resolve them.

EXHIBIT II

PROPOSED INCENTIVES RESEARCH BUDGET

(IN THOUSANDS OF DOLLARS)

OPTION I

	1970	1971	1972	1973	1974
Inventory, Projections & Surveillance	125	100	100	100	100
Automobiles	150	100	100	100	
			125	200	250
Garbage, Yard trimmings		100	100	100	100
		(Technology development is part of existing program)			
Paper Products		200	100	100	100
			100	100	100
			125	175	250
Sub-Total A	275	500	750	875	900
Bottles		100	100	100	100
			100	100	100
			(No Technological Development is needed)		
Cans		200	100	100	100
			175	250	350
Sub-Total B	275	800	1225	1425	1550
Demolition Rubble		75	100	100	100
			100	125	150
Tires		80	100	100	100
			175	100	125
Plastic & Foam		90	100	100	100
			100	125	150
Large Appliances		150	100	100	100
			125	200	250
TOTAL	275	1195	2125	2375	2625

(a) The underlined numbers refer to the price elasticity and subsidy studies.

(b) The numbers in the solid rectangles refer to the costs of pilot demonstrations

(c) The numbers in the dotted rectangles refer to technological R & D.

OPTION 2

	1970	1971	1972	1973	1974
Sub-Total B	275	800	1225	1425	1550
Demolition rubble			75	100	100
				100	125
Tires			80	100	100
				75	100
Plastic & Foam			90	100	100
				100	125
Large Appliances			80	100	100
				75	100
TOTAL	275	800	1550	2175	2400

EXHIBIT II

OPTION 3

	1970	1971	1972	1973	1974
Sub-Total A	275	500	750	875	900
				[175]	[250]
Bottles			100	100	100
				100	100
Cans			200	100	100
				[175]	[250]
Demolition rubble				75	100
					[100]
Tires				80	100
					[75]
Plastic & Foam				90	100
					[100]
Large Appliances				150	100
					[125]
TOTAL	275	500	1050	1920	2500

EXHIBIT II

OPTION 4

	1970	1971	1972	1973	1974
Sub-total A	275	500	750	875	900
Bottles			100	100	100
				100	100
Cans			200	100	100
				175	250
Demolition rubble					75
Tires					80
Plastic & Foam					90
Large Appliances					150
TOTAL	275	500	1050	1350	1845